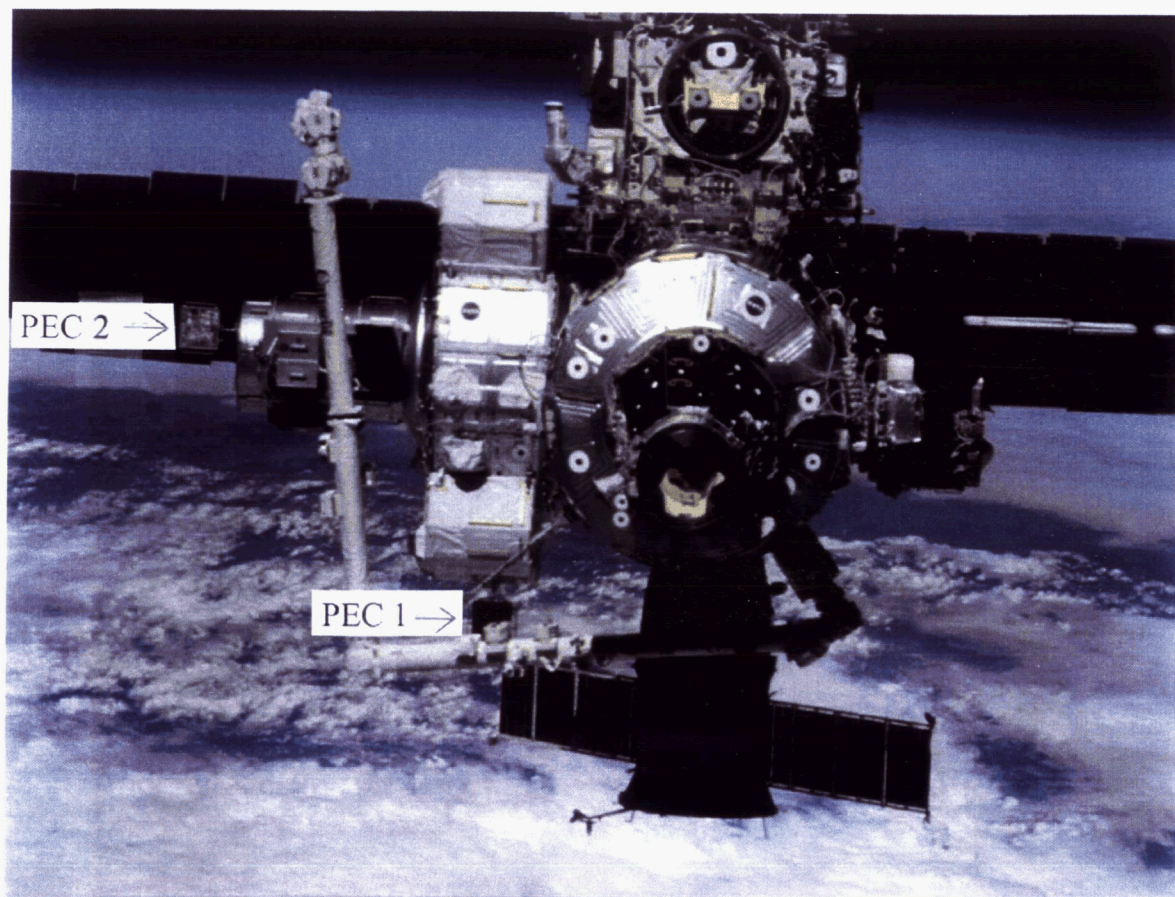


MISSE 1 & 2 Tray Temperature Measurements

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MISSE Post-Retrieval Conference
Orlando FL, June 2006

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ABSTRACT

The Materials International Space Station Experiment (MISSE 1 & 2) was deployed August 10, 2001 and retrieved July 30, 2005. This experiment is a co-operative endeavor by NASA-LaRC, NASA-GRC, NASA MSFC, NASA-JSC, the Materials Laboratory at the Air Force Research Laboratory, and the Boeing Phantom Works. The objective of the experiment is to evaluate performance, stability, and long term survivability of materials and components planned for use by NASA and DOD on future LEO, synchronous orbit, and interplanetary space missions. Temperature is an important parameter in the evaluation of space environmental effects on materials.

The MISSE 1 & 2 had autonomous temperature data loggers to measure the temperature of each of the four experiment trays. The MISSE tray-temperature data loggers have one external thermistor data channel, and a 12 bit digital converter. The MISSE experiment trays were exposed to the ISS space environment for nearly four times the nominal design lifetime for this experiment. Nevertheless, all of the data loggers provided useful temperature measurements of MISSE. The temperature measurement system has been discussed in a previous paper. This paper presents temperature measurements of MISSE payload experiment carriers (PECs) 1 and 2 experiment trays.

INTRODUCTION

The International Space Station (ISS) (figure 1) is a key element of the NASA Human Exploration and Development of Space Enterprise. The ISS will expand our knowledge and help bring the benefits of space to Earth. The first element of the ISS was launched in November 1998. The ISS became inhabited in October 2000.

The Long Duration Exposure Facility (LDEF) and the Mir Environmental Effects Payload (MEEP) utilized hardware returned from low-Earth-orbit (LEO) to study and measure space and spacecraft-induced environmental effects. A section of a solar array returned from the Mir space station has also been extensively studied for power degradation, micrometeoroid, and contamination effects.

Numerous papers, including references 1-6 have been written on analyses of the returned hardware. The LDEF had more than six years of space exposure, the MEEP hardware had more than one year of space exposure, and the returned Mir solar array section had more than ten years of space exposure.

Temperature is an important parameter in space environmental effects on materials and hardware. In general external hardware temperatures are complex functions of angle of the hardware surface to the sun, the hardware absorptivity and emissivity, thermal mass, conductivity to adjacent hardware and previous thermal history of the hardware. The angle of the hardware surface to the sun is a complex function of the spacecraft position in orbit (which continuously changes during an orbit), the plane of the orbit with respect to the sun (which changes or precesses from orbit to orbit and effects time-in shadow or seasonal changes), location and orientation of the hardware on the spacecraft, and orientation of the spacecraft (attitude) with respect to the orbit. Thus computations of hardware temperature histories are complex and costly, even when spacecraft attitude information is available⁷. This is compounded by the requirement for solar absorbances, thermal emittances, thermal masses, and heat conductances at hardware interfaces which generally are not known.

No measured temperature data is available for MEEP, although some temperature predictions were computed. Some time-in-shadow data (which correlates inversely with temperature) are available for MIR and hence the returned solar panel⁶. Temperature data was recorded during the first year of space exposure of LDEF by the THERM system^{8,9}. The temperature measurement system for MISSE PECs 1-4 has been described in a previous paper¹⁰.

The ISS is designed to fly in two standard attitudes and three special attitudes because of temperature, docking, and re-boost requirements. The primary flight attitude is with the x-axis in the velocity vector (ram) direction and the z-axis toward the Earth (XVV Z Nadir TEA). The second standard attitude is with the X-axis perpendicular to the orbit plane (XPOP) which allows the solar arrays to track the sun for maximum power generation. Typically

the external hardware temperatures will vary during an orbital period (similar to terrestrial day/night and orbit precession (similar to terrestrial seasons).

Alternatively, measured temperature histories can be used to confirm orientation maneuvers as well as changes in hardware radiative properties.

DIGITAL TEMPERATURE DATA LOGGERS

Temperature data loggers are clamped to the bottom (unexposed) side of each MISSE tray (figure 2). The MISSE tray-temperature data-loggers (figure 3) have one external thermistor data channel, and a 12 bit analog to digital converter. The thermistor was clamped to the center of the aluminum experiment tray. These data loggers have a nominal temperature recording range of -50°C to 150°C and a nominal temperature resolution of 0.1°C . These data loggers have an expanded non-volatile memory of 76,000 samples for more than 20 years retention without power. The data logger power source is a 3.6v internal lithium battery with a nominal 10 year lifetime. The clock accuracy is plus or minus one minute per month.

The data loggers are compatible with a Windows software package that allows the user to configure (program) the data logger, download, display in graphical or tabular form, and save the stored data for export and archiving. The data loggers have selectable sampling rates, instant or delayed sampling start, and full or overwrite storage modes. The Spectrum software permits plotting or printing data for any time interval and is user friendly.

The data loggers are housed in injection-molded ABS plastic case 71 x 53 x 18 mm and weigh 62 grams (2.2 oz). The data loggers were subjected to preflight environmental tests⁷.

MISSION/DATA RECORDING PERIODS

The MISSE PECs 1 and 2 tray-temperature data-loggers were programmed for two years of data acquisition assuming that the nominal one year of space exposure would occur between May 2001 and May 2003. The actual space exposure was August 16, 2001 through July 30, 2005. PEC 1 was attached to a handrail on the base of the Airlock module, and PEC 2 was attached to a handrail on the outward side of the airlock-hatch-extension (figure 4). The atomic oxygen (AO) trays were facing the nominal forward (ram) ISS orbiting direction. The ultraviolet exposure (UV) trays were facing the nominal wake ISS orbital direction. As a consequence of the extended space exposure and that the data loggers were programmed for wrap mode of data storage, the tray temperatures of PEC 1 UV, PEC 2 AO, and PEC 2 UV were recorded for the period of September 25, 2003 through September 28, 2005. A very small sample of the tabular data for PEC 1 UV is presented in Table 1. PEC 1 AO data logger quit recording temperatures after 13 months from start-data acquisition (June 10, 2001), so that the first 10 months (August 16, 2001 to June 4, 2002) of space exposure temperatures are available for PEC 1 AO. The times retrieved from the data loggers are derived backward from the PC clock, and hence the time and date of the PEC 1 AO data must be shifted back 3 years, 3 months, and 21 days to the start of data acquisition of the data logger.

REPRESENTATIVE TEMPERATURE DATA

The temperature data can be plotted for the full time period of data acquisition, for precession periods, and/or for orbital periods. Temperature plots of the full time periods of the four data loggers are shown in figures 5 – 8. The full time plots are especially useful for quickly determining the maximum and minimum temperatures experienced by the experiment trays during the space exposure and which are determined primarily by the ISS orientation relative to the Sun. The precession (seasonal) periods of several weeks (figures 9 - 12) show the range of temperatures experienced by the experiment trays due to precession of the ISS orbit around the Earth every 60 days. The short period temperature changes are due to the 90 minute period of the ISS orbiting the Earth, and are shown in figures 13 – 16. They are somewhat analogous to the Earth's 24 hour day/night cycle.

A post-flight photograph of the PEC 1 AO experiment tray is shown in figure 17. Although there are many samples of widely varying solar absorbance (color) and thermal emittance, the PEC 1 AO experiment tray (as well as the other 3 experiment trays) thermal behavior is probably driven primarily by the areas of anodized aluminum which is in thermal contact with the aluminum experiment tray plate on which the thermistor is mounted.

Figure 5 shows that except for a few very brief excursions (probably due to temporary reorientations of the ISS) the maximum temperature experienced by the PEC 1 AO experiment tray was about 40 degrees Fahrenheit, and the minimum temperature was about minus 60 degrees Fahrenheit with an average temperature of about minus 20 degrees Fahrenheit. The PEC 1 AO experiment tray was the coldest of the four experiment trays. This may have contributed to the apparent failure of that tray's data logger clock. It is noted that PEC 1 AO tray is in shadow in

figure 4 while PEC 2 AO tray is sunlight. The PECs 1 and 2 were deployed near sunspot maximum¹¹, and hence the high energy particle radiation may have contributed to the failure of the PEC AO data logger after ten months of space exposure.

A post-flight photograph of the PEC 2 AO experiment tray is shown in figure 18. Figure 6 shows that except for a few brief excursions the maximum temperature of the PEC 2 AO experiment tray is about 40 degrees Fahrenheit, and the minimum tray temperature is about minus 15 degrees Fahrenheit with an average temperature of about 20 degrees Fahrenheit. Thus the maximum temperature of the AO trays was similar, but the lower temperature of PEC 1 AO tray was colder by more than 20 degrees Fahrenheit than the AO tray of PEC 2.

A post-flight photograph of PEC 1 UV experiment tray is shown in figure 19. Figure 7 shows that for several relatively short periods the maximum temperature of the PEC 1 UV experiment tray was well over 100 degrees Fahrenheit, and that the minimum temperature was about minus 60 degrees Fahrenheit with an average temperature around minus 20 Fahrenheit.

A post-flight photograph of PEC 2 UV experiment tray is shown in figure 20. Figure 8 shows the maximum temperature of the PEC 2 UV experiment tray was about 130 degrees Fahrenheit, and that except for a few brief excursions the minimum temperature was around zero degrees Fahrenheit. The average temperature of PEC 2 UV experiment tray was about 60 degrees Fahrenheit. Thus PEC 2 UV tray was the warmest of the four experiment trays, and PEC 1 UV was the second warmest of the experiment trays.

DISCUSSION AND RESULTS

Temperature measurements of space-exposed hardware have been limited. This has driven the need to predict (compute) expected extreme temperatures of critical exposed surfaces such as radiators and thermal control surfaces for survivability analyses. External hardware temperatures are strongly affected by spacecraft orientation and operations. Measured temperature histories can be used to confirm changes in spacecraft orientation in many cases, in addition to providing valuable information on materials and hardware. For example, changes in solar radiation absorptivity, and or emmissivity resulting from material degradation of contaminate films usually cause corresponding changes in temperatures of the exposed hardware. This can be used to deduce amounts of contaminate molecular deposition and retention since most molecular contaminants are instantaneously fixed by relatively small amounts of solar ultraviolet radiation and subsequently are darkened by additional solar UV. The ISS is the largest and most complex spacecraft ever assembled. Many of the modules are too large to have vacuum cleanliness certifications performed. The number of planned orbital operations, and assembly and supply operations is greater than for any other spacecraft. These circumstances greatly increase the value and utility of external hardware temperature measurements.

A temperature data logger system has been integrated into the MISSE experiment trays. The temperature data loggers used in the MISSE trays are one type of programmable data loggers that can be used in autonomous space systems, which are returned to Earth.

There are several specific conclusions and results from this experiment:

1. The temperature sensors (-50F to 150F thermistors) chosen for this experiment were well suited for the experiment.
2. The temperature data loggers performed very well on this extended mission with 3 of the 4 experiment tray data loggers providing full storage capacity of temperature data, and the fourth data logger providing more than half of the maximum storage capacity of temperature data. That is, there was 90% recovery of mission-objective temperature data.
3. The sampling rate (15 minutes) was more than adequate to characterize the temperature cycles.
4. The temperature data show very well behaved orbital temperature cycles.
5. The temperature data show the large effects of orbit precession on external temperatures, and
6. The temperature data show the large effects of hardware location on the ISS on external temperatures.

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Table 1
PEC 1 UV Tabular Data For Four Orbits

Description:	Channel 1
Maximum Value:	-43.60 F
Average Value:	-49.90 F
Minimum Value:	-56.11 F
9/25/2003 12:14:00 PM	-52.38 F
9/25/2003 12:29:00 PM	-45.78 F
9/25/2003 12:44:00 PM	-44.95 F
9/25/2003 12:59:00 PM	-49.05 F
9/25/2003 1:14:00 PM	-53.82 F
9/25/2003 1:29:00 PM	-56.11 F
9/25/2003 1:44:00 PM	-52.73 F
9/25/2003 1:59:00 PM	-45.78 F
9/25/2003 2:14:00 PM	-43.60 F
9/25/2003 2:29:00 PM	-47.24 F
9/25/2003 2:44:00 PM	-52.38 F
9/25/2003 2:59:00 PM	-55.32 F
9/25/2003 3:14:00 PM	-53.09 F
9/25/2003 3:29:00 PM	-46.93 F
9/25/2003 3:44:00 PM	-43.87 F
9/25/2003 3:59:00 PM	-46.64 F
9/25/2003 4:14:00 PM	-51.34 F
9/25/2003 4:29:00 PM	-54.94 F
9/25/2003 4:44:00 PM	-53.82 F
9/25/2003 4:59:00 PM	-48.44 F
9/25/2003 5:14:00 PM	-44.68 F
9/25/2003 5:29:00 PM	-46.93 F
9/25/2003 5:44:00 PM	-52.02 F
9/25/2003 5:59:00 PM	-55.71 F

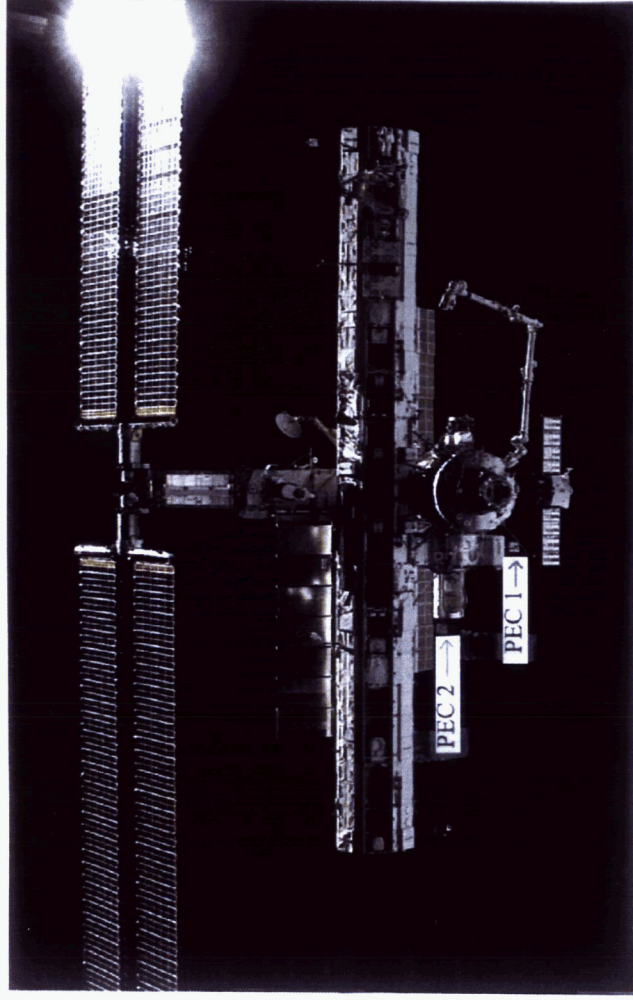


Figure 1.- December 2, 2002 photograph of the ISS.



Figure 3.- Photograph of a temperature data logger.

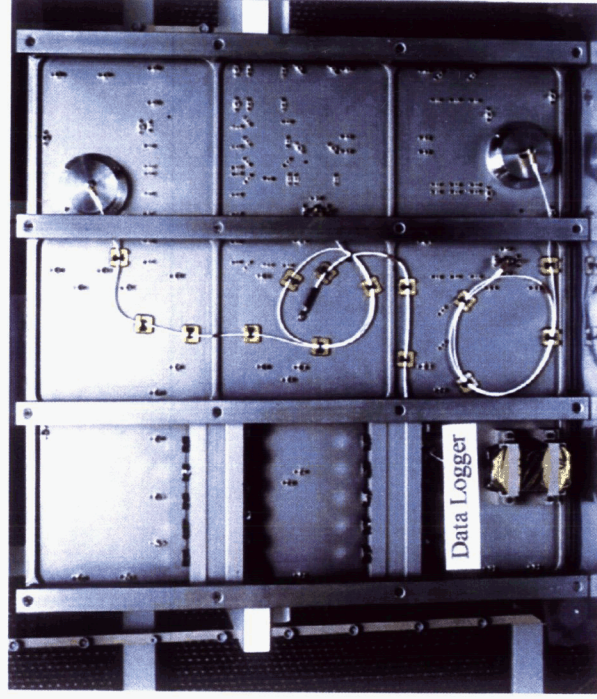


Figure 2.- Photograph of the bottom of an experiment tray.

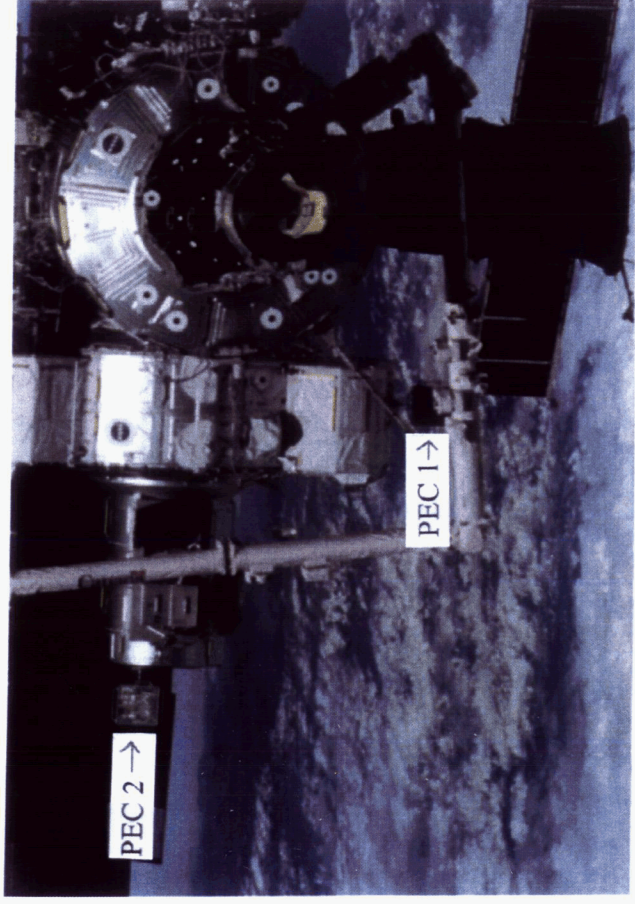


Figure 4.- Photograph of PECs on the airlock-hatch-extension.

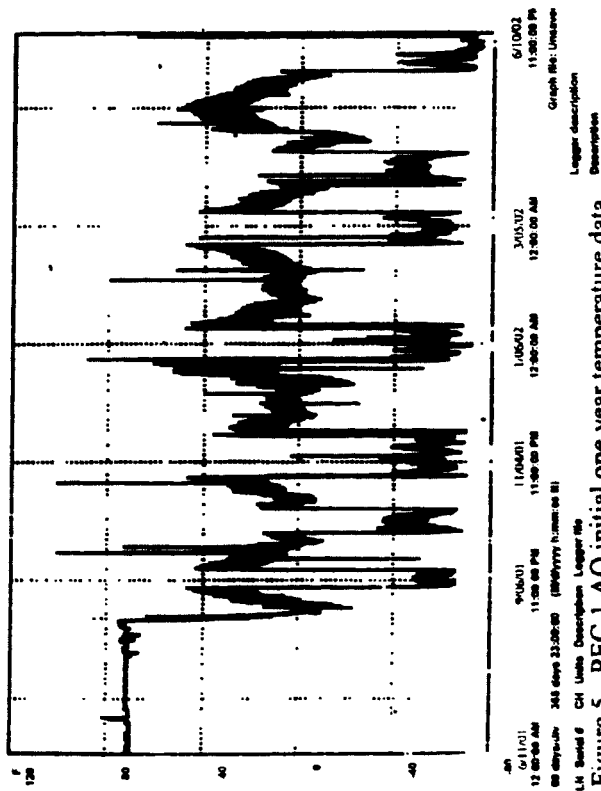


Figure 5.- PEC 1 AO initial one year temperature data.

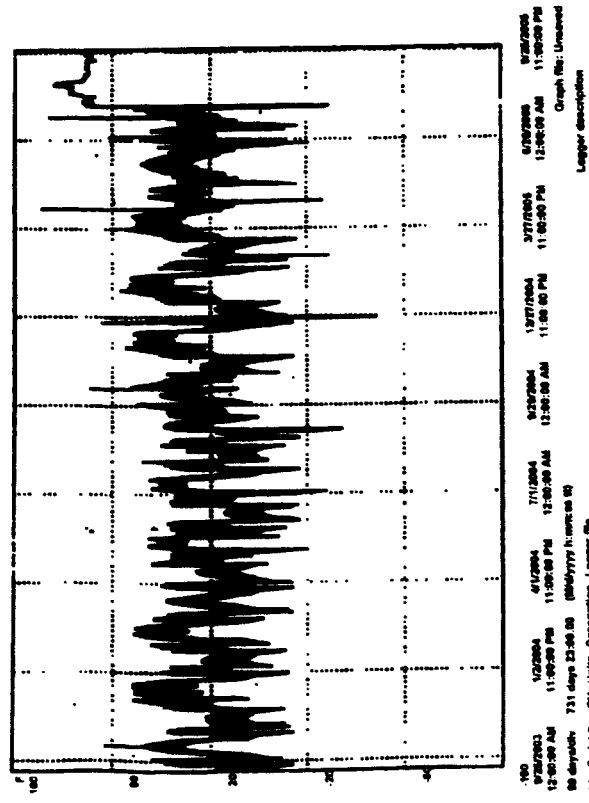


Figure 6.- PEC 2 AO last two years temperature data.

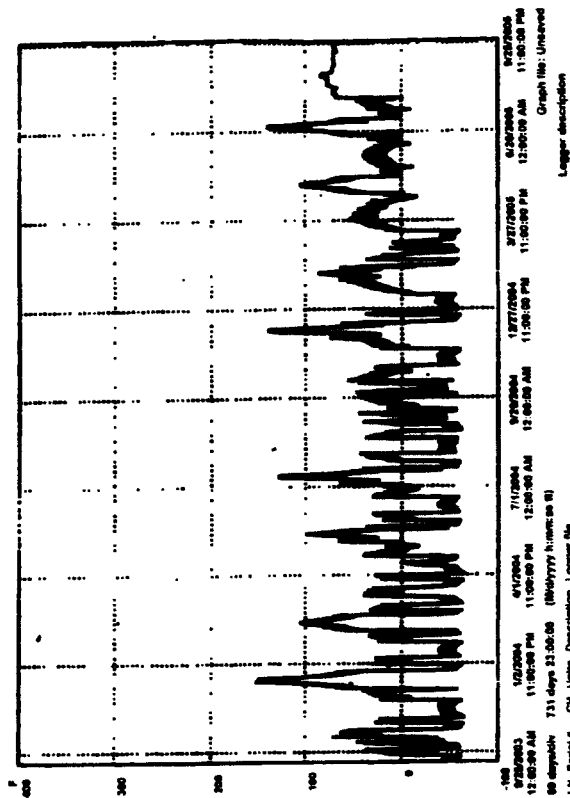


Figure 7.- PEC 1 UV last two years temperature data.

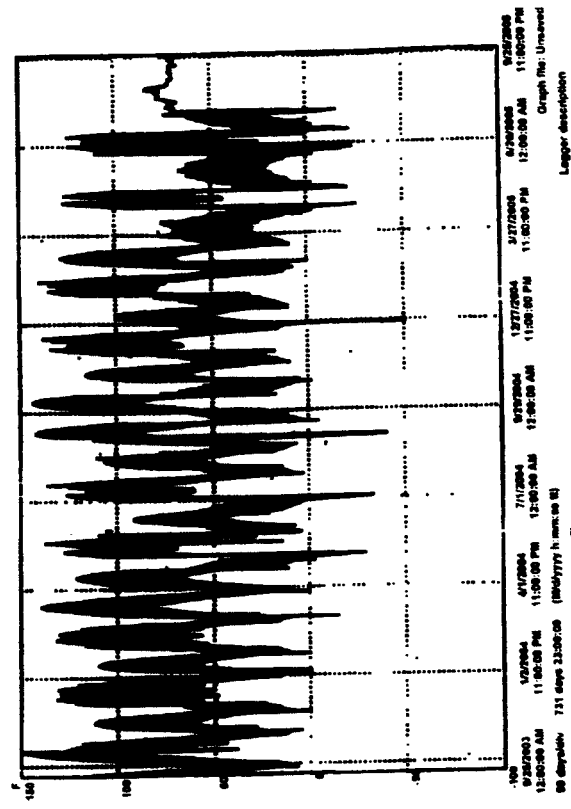


Figure 8.- PEC 2 UV last two years temperature data.

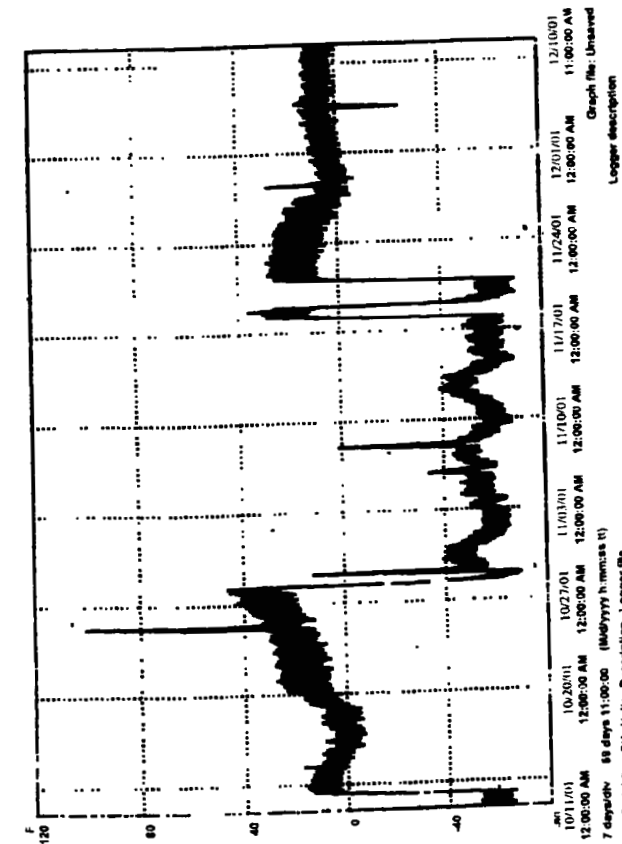


Figure 9.- PEC 1 AO precession period temperature data.

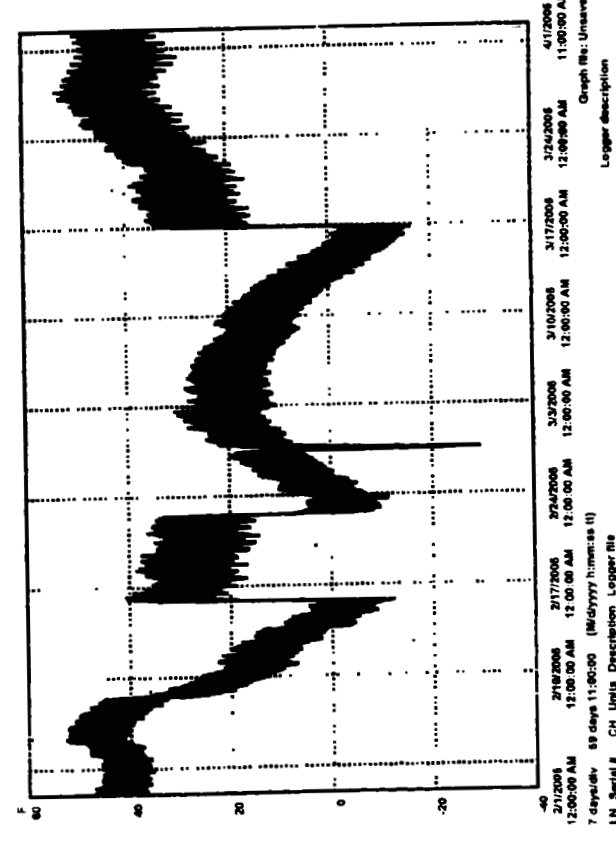


Figure 10.- PEC 2 AO precession period temperature data.

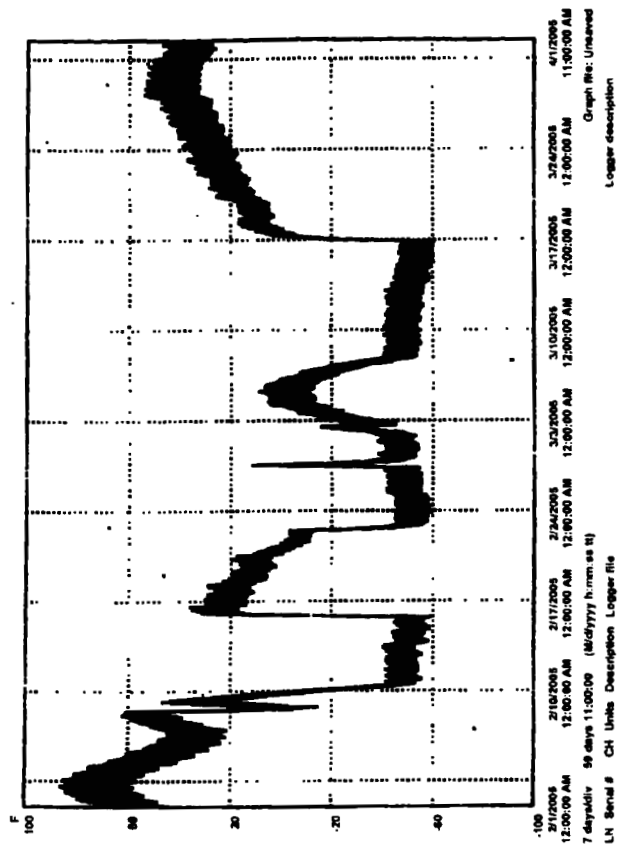


Figure 11.- PEC 1 UV precession period temperature data.

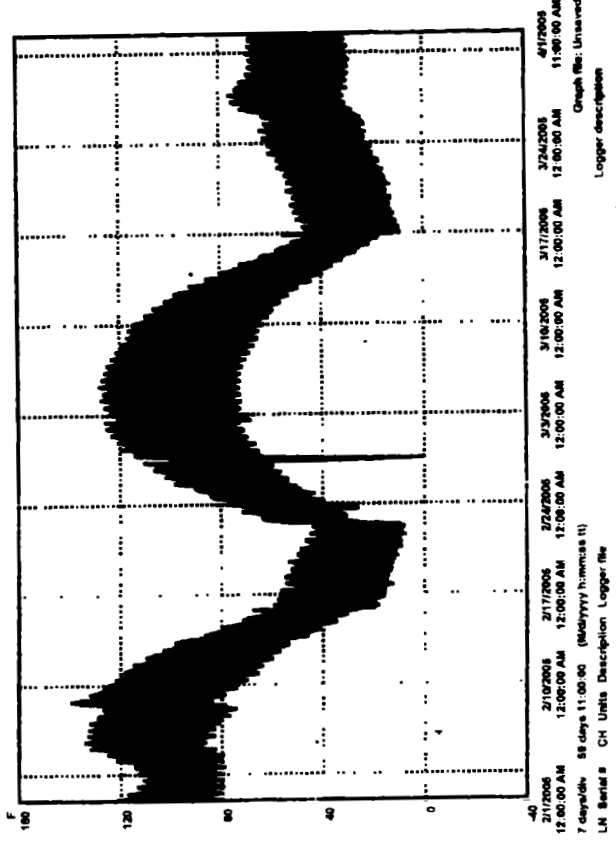


Figure 12.- PEC 2 UV precession period temperature data.

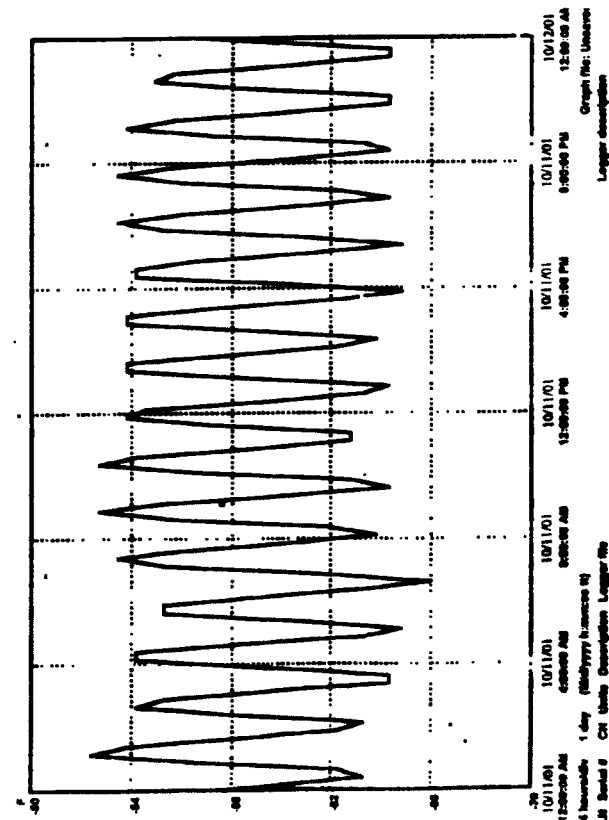


Figure 13. - PEC 1 AO one Earth-day temperature data.

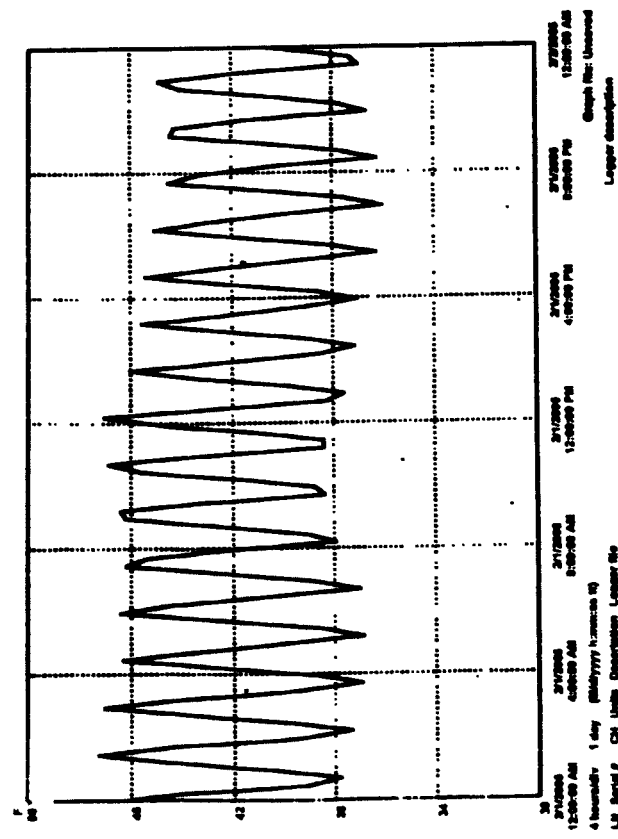


Figure 14. - PEC 2 AO one Earth-day temperature data.

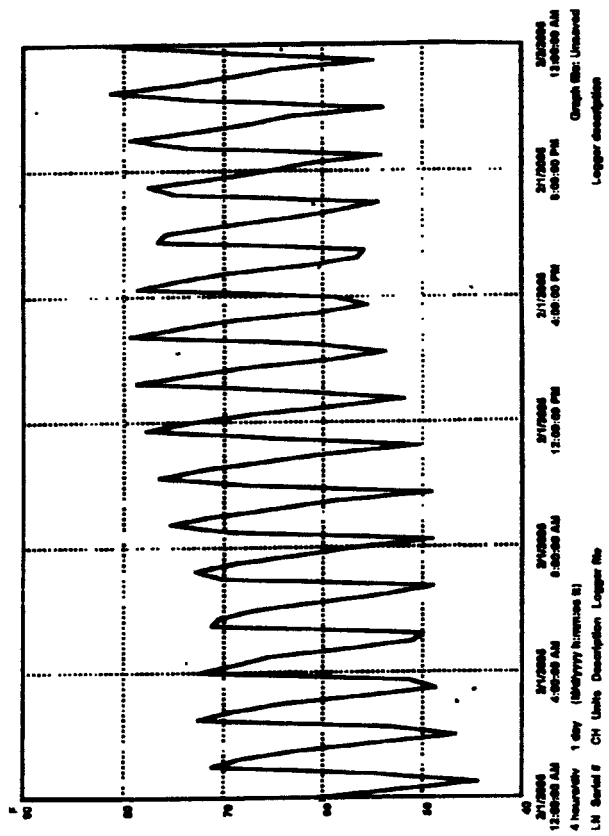


Figure 15. - PEC 1 UV one Earth-day temperature data.

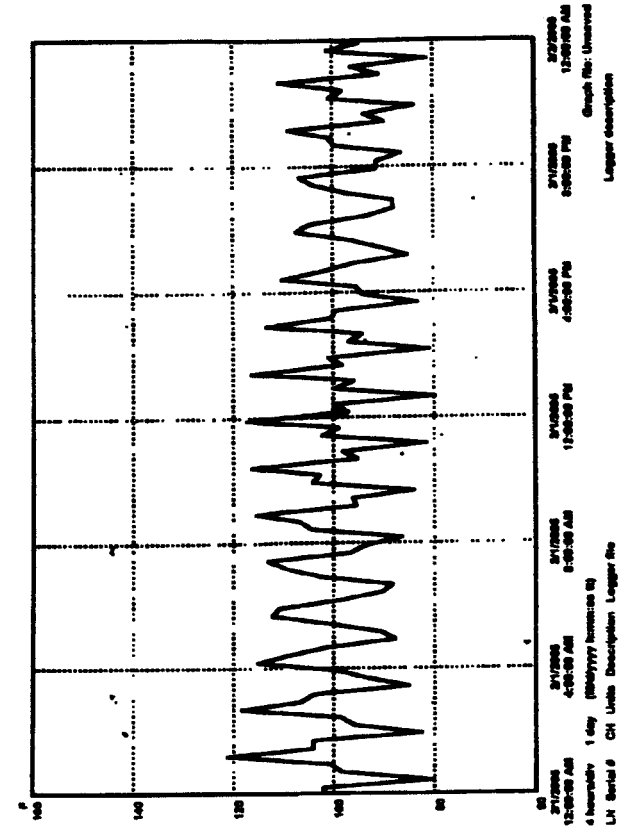


Figure 16. - PEC 2 UV one Earth-day temperature data.

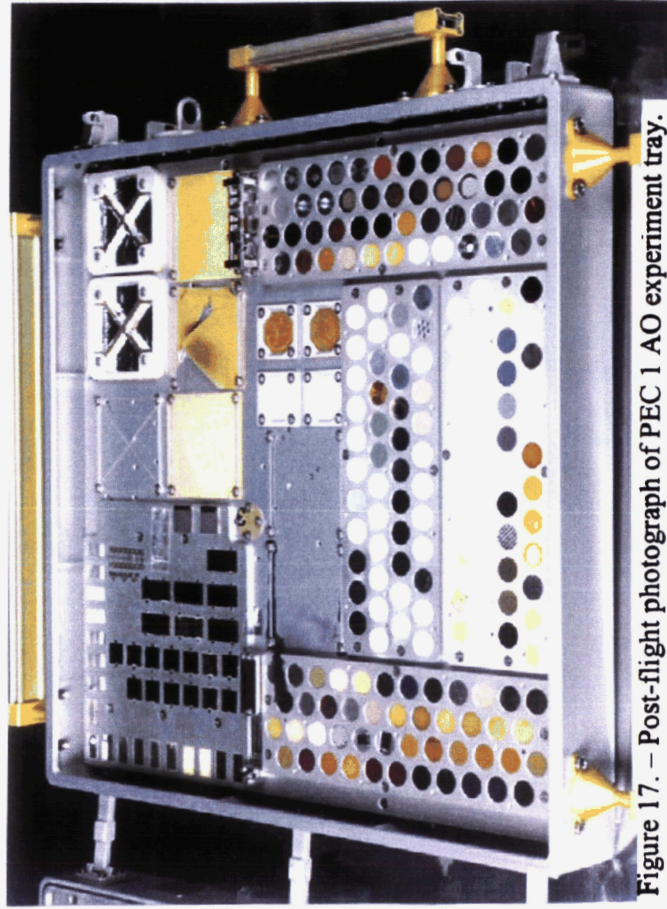


Figure 17. – Post-flight photograph of PEC 1 AO experiment tray.

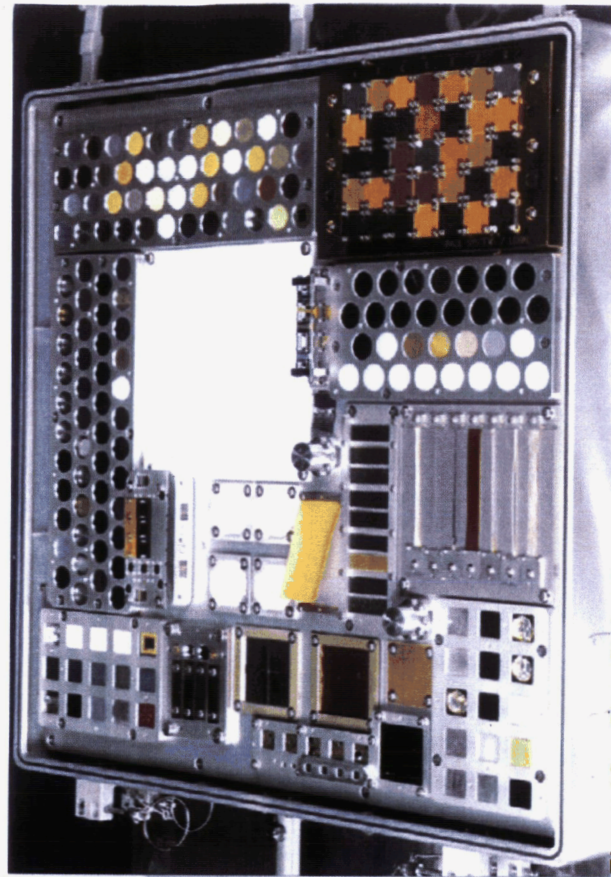


Figure 19. – Post-flight photograph of PEC 1 UV experiment tray.

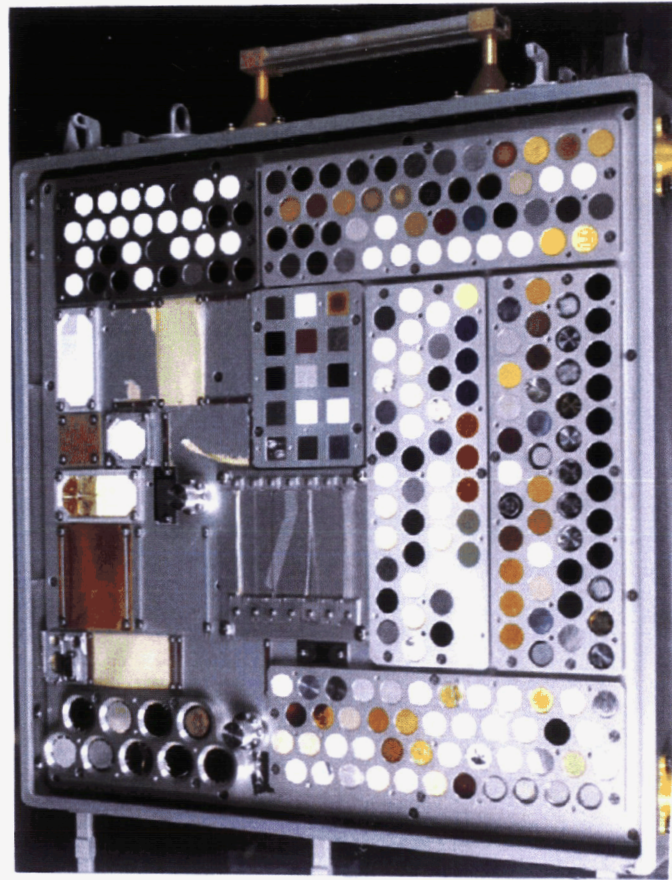


Figure 18. – Post-flight photograph of PEC 2 AO experiment tray.

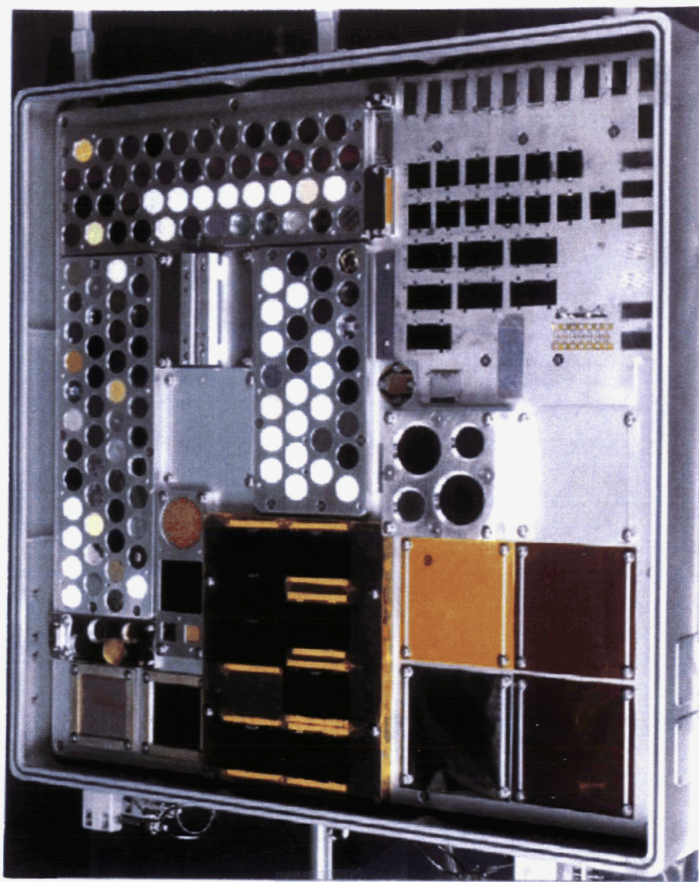


Figure 20. – Post-flight photograph of PEC 2 UV experiment tray.